

# Air quality forecasts using the NASA GEOS model: A unified tool from local to global scales

K. Emma Knowland  
(USRA/GESTAR, GMAO)



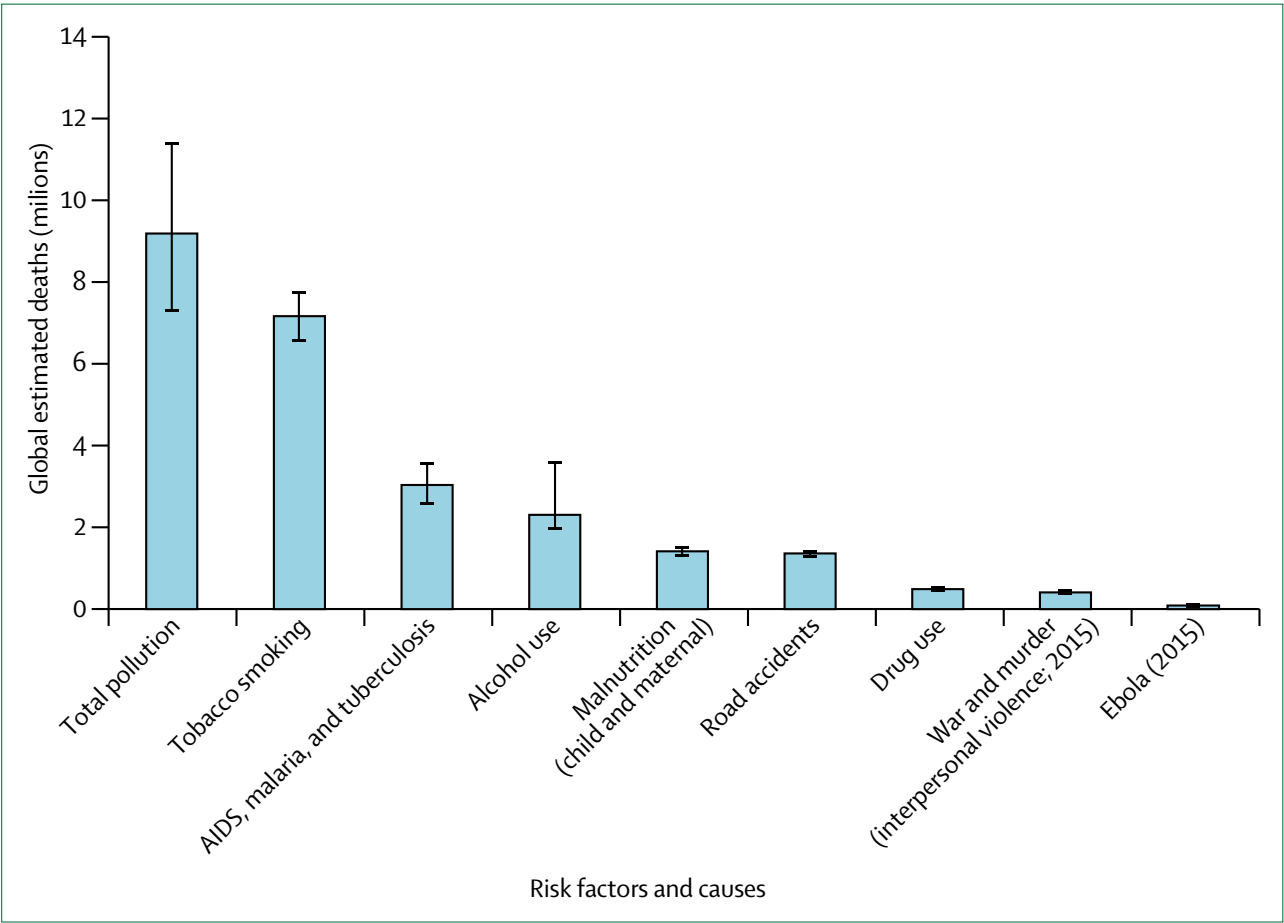
In collaboration with

GMAO: Christoph Keller, J. Eric Nielsen, Clara Orbe, Lesley Ott,  
Steven Pawson, Emily Saunders

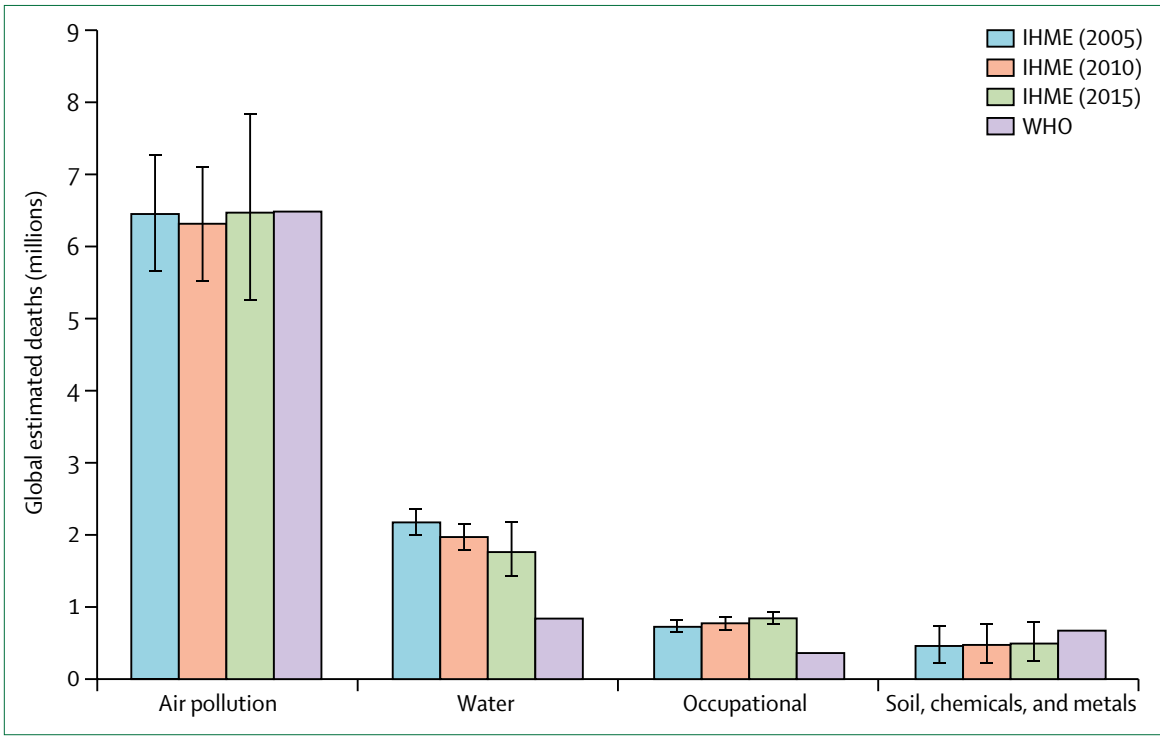
Atmospheric Chemistry and Dynamics Laboratory: Bryan Duncan,  
Melanie Follette-Cook, Junhua Liu, Julie Nicely



# Why we care about air quality



**Figure 5: Global estimated deaths by major risk factor and cause, 2015**  
Using data from the GBD Study, 2016.<sup>41</sup>



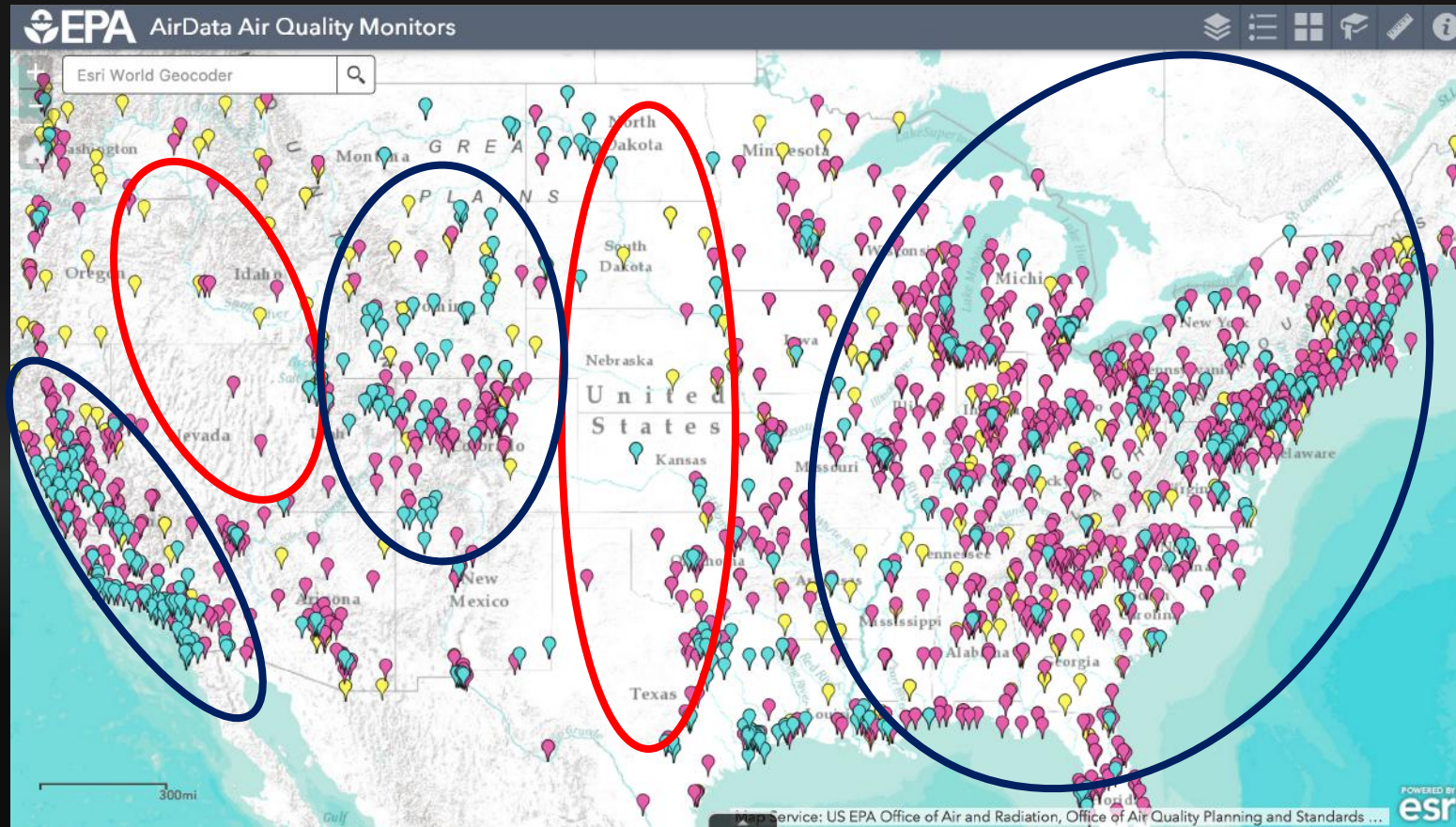
**Figure 4: Global estimated deaths (millions) by pollution risk factor, 2005-15**  
Using data from the GBD study<sup>42</sup> and WHO.<sup>99</sup> IHME=Institute for Health Metrics and Evaluation.

The Lancet Commissions, 2017

# Why do we need models?

Surface observations of pollutants are point source measurements which can be **sparse**.

<https://epa.maps.arcgis.com>

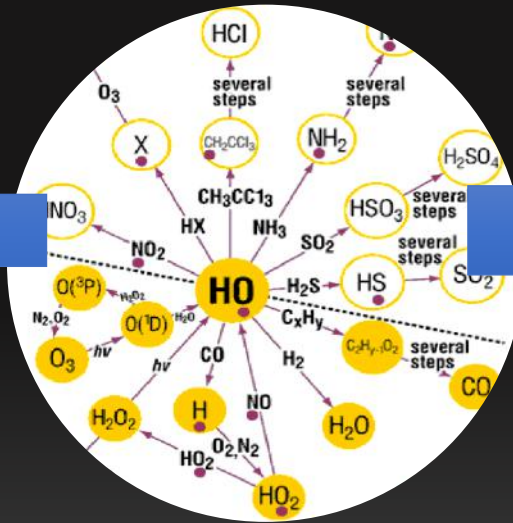
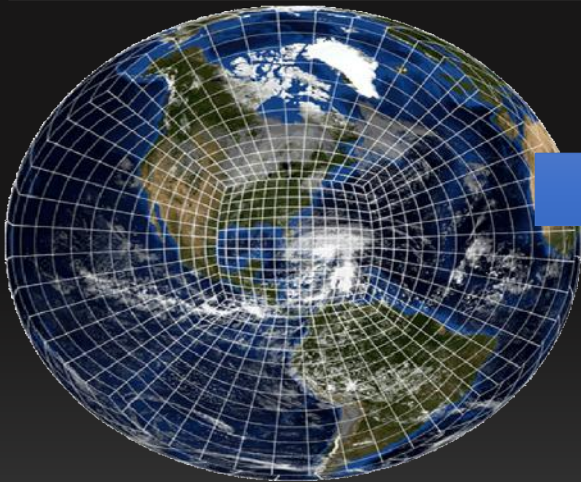


$O_3$   
 $PM_{2.5}$   
 $NO_2$

# Composition forecasting system (GEOS-CF)

Running since March 2017 (still in test mode)

NASA GEOS Earth  
System Model



GEOS - CF

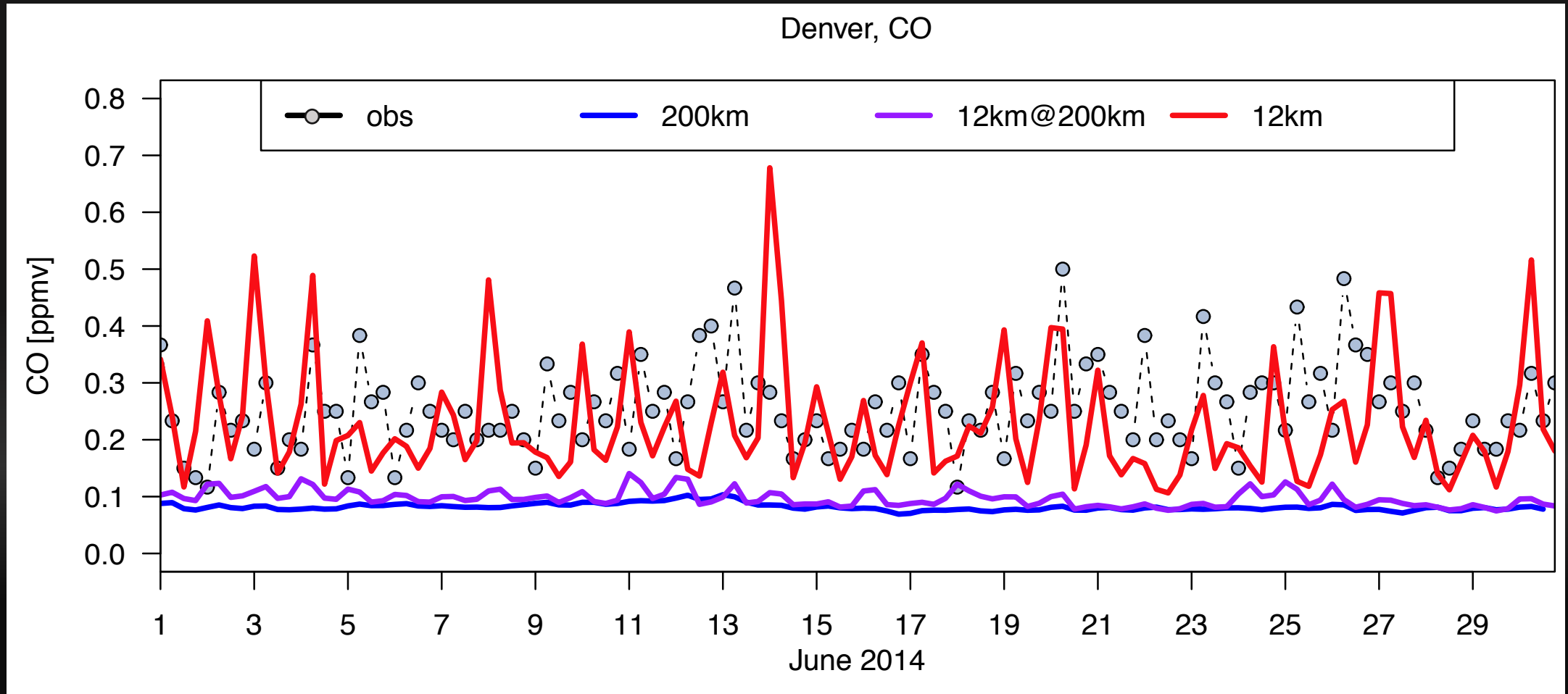
GEOS - FP

GEOS - Chem

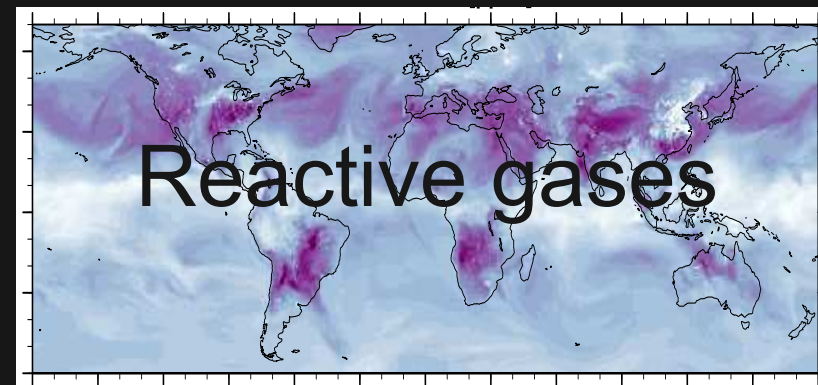
- 1-day analysis
- 5-day forecast
- $O_3$ ,  $NO_x$ , VOCs, PM ...
- c360 resolution ( $0.25^\circ$ )



# Higher resolution critical to resolve features relevant to air quality



# Contributors to Air Pollution



## ➤ Particulate matter (PM):

- Organic Carbon
- Black Carbon
- Sea salt
- Nitrate
- Sulfate
- Dust

## ➤ Ozone ( $O_3$ )

## ➤ Nitrogen dioxide ( $NO_2$ )

## ➤ Sulfur dioxide ( $SO_2$ )

## ➤ Volatile organic compounds (VOCs):

e.g., Formaldehyde, Benzene, Toluene, and many more...

GOCART

GEOS-Chem

# Health Air Quality Index (HAQI or AQHI)

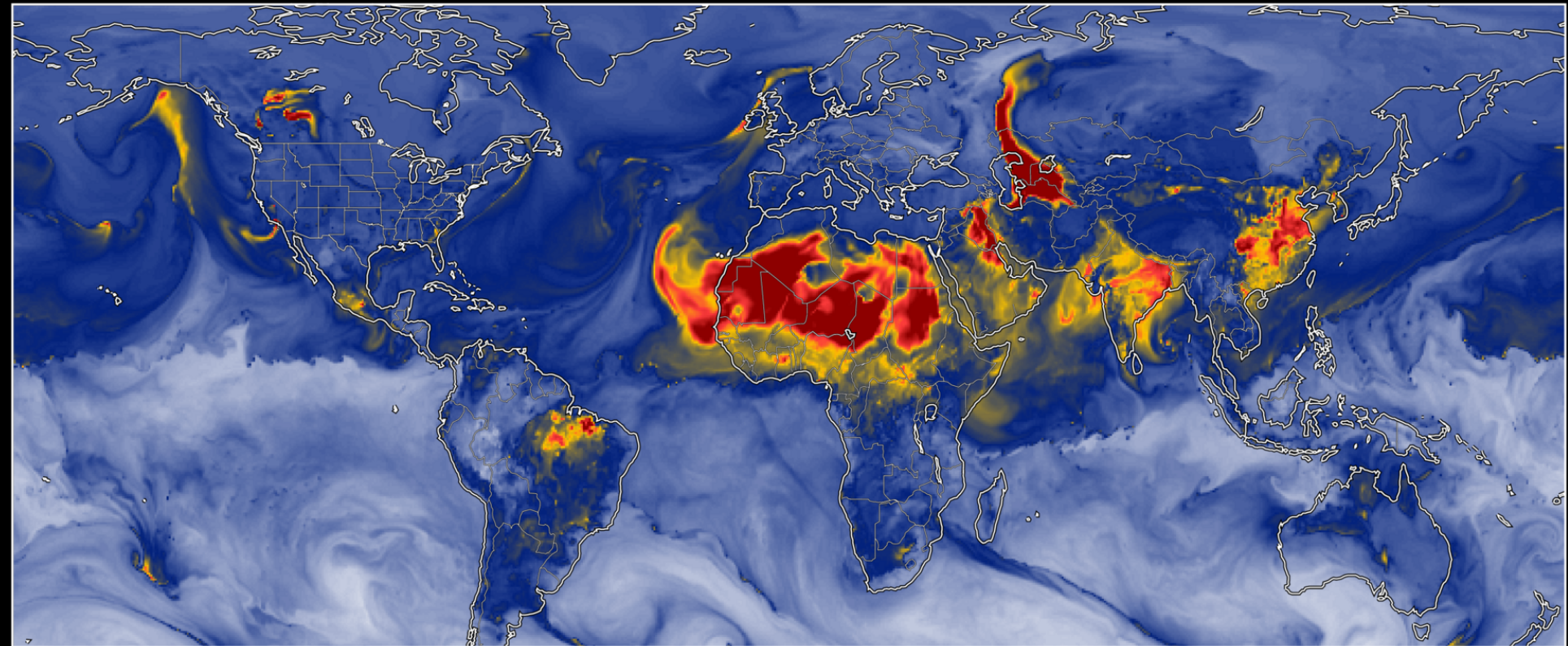
- HAQI is a function of  $PM_{2.5}$ ,  $O_3$ ,  $NO_2$

$$AQHI = \left(\frac{1000}{10.4}\right) \times [(e^{0.000537 \times O_3} - 1) + (e^{0.000871 \times NO_2} - 1) + (e^{0.000487 \times PM_{2.5}} - 1)]$$

(Stieb et al., 2008, J. Air & Waste Manage. Assoc.)

# Health Air Quality Index (HAQI or AQHI)

- HAQI is a function of  $\text{PM}_{2.5}$ ,  $\text{O}_3$ ,  $\text{NO}_2$



GEOS-5 1/4°

GEOS-Chem v11-02



GMAO

Wed 6 December  
2017

Thu 7 December

Fri 8 December

Sat 9 December

Sun 10 December

Global Modeling and Assimilation Office  
NASA Goddard Space Flight Center

Good

Moderate

Unhealthy

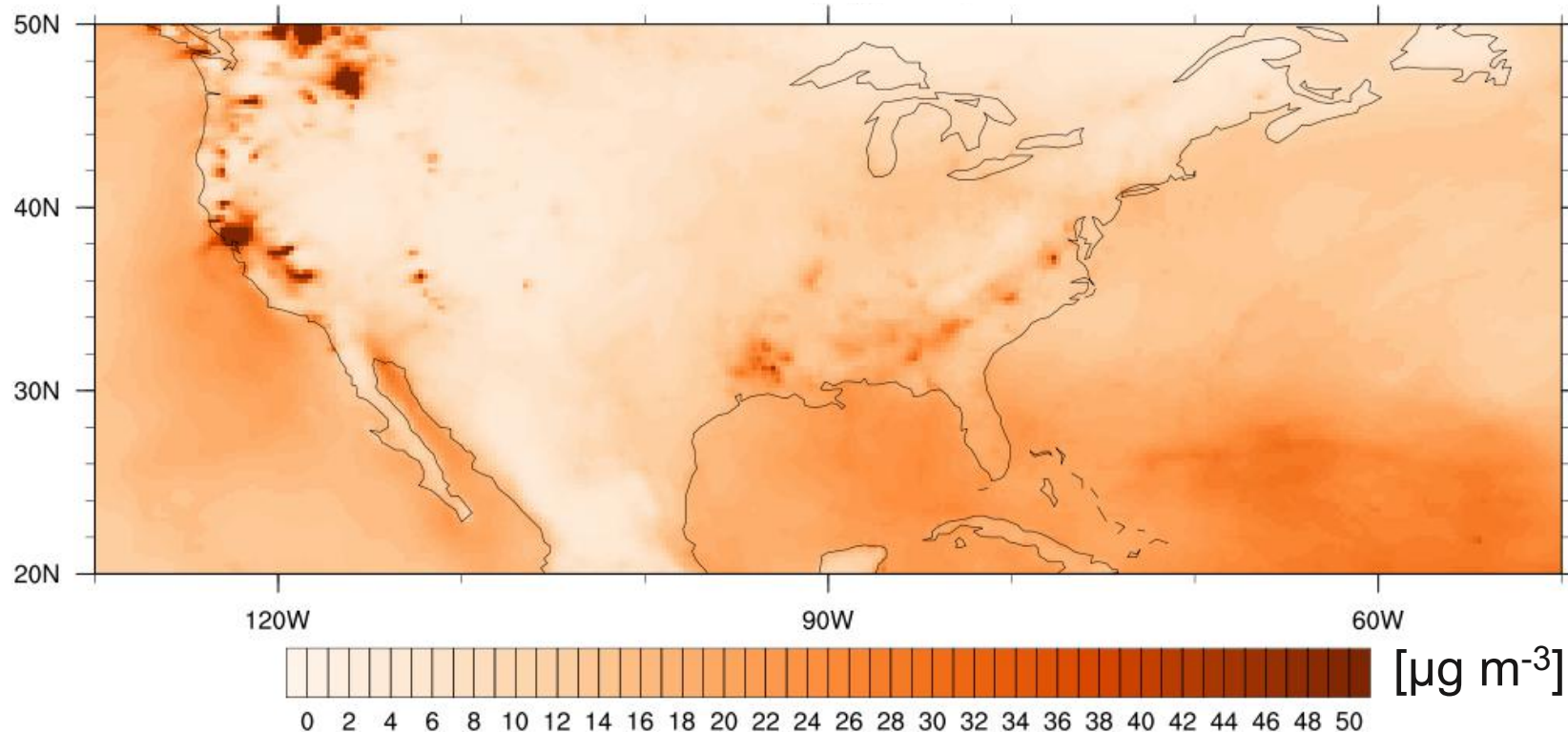
Very Unhealthy

Atmospheric Chemistry Modeling Group  
Harvard University



# Health Air Quality Index (HAQI or AQHI)

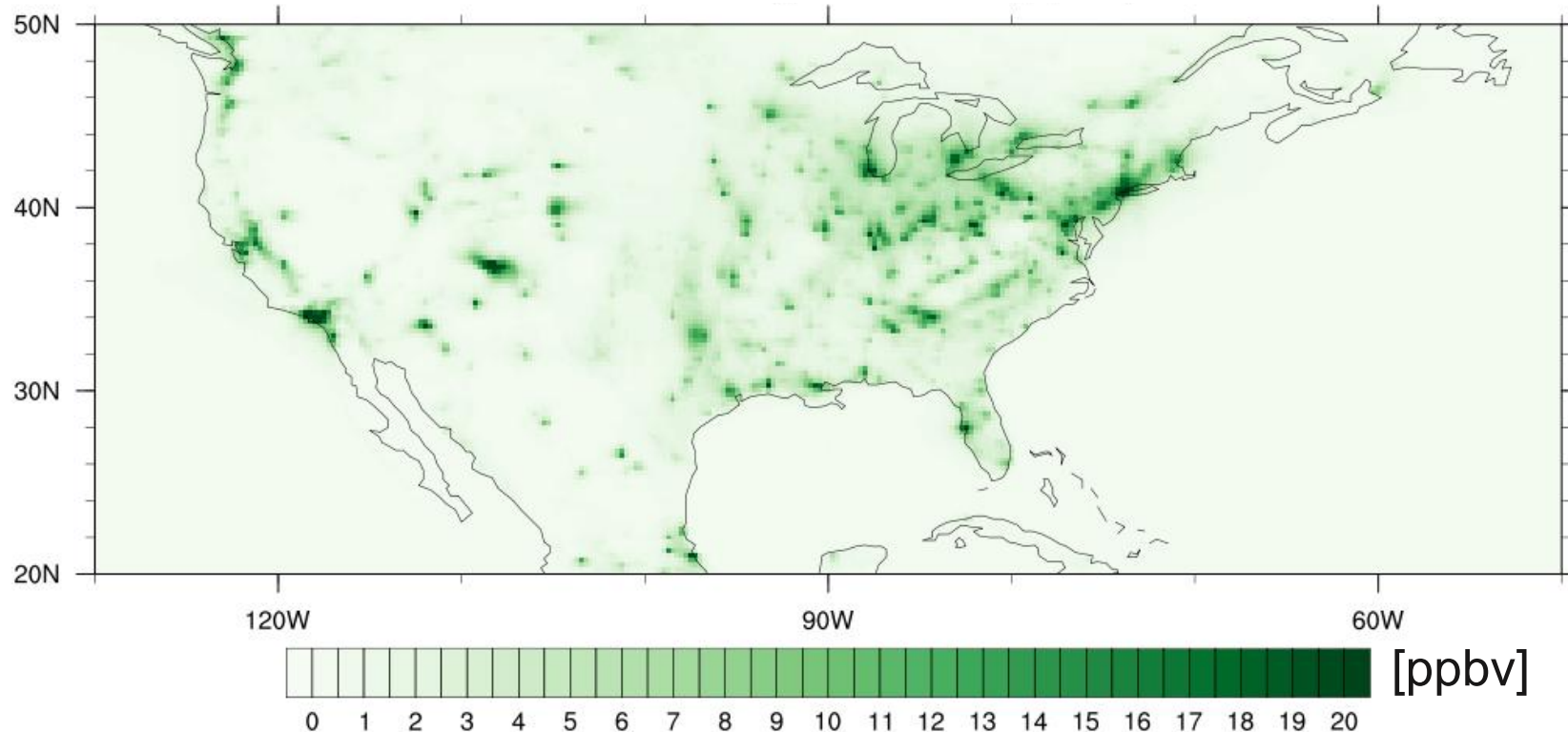
monthly mean  $\text{PM}_{2.5}$



➤  **$\text{PM}_{2.5}$  driver of spatial gradients**

# Health Air Quality Index (HAQI or AQHI)

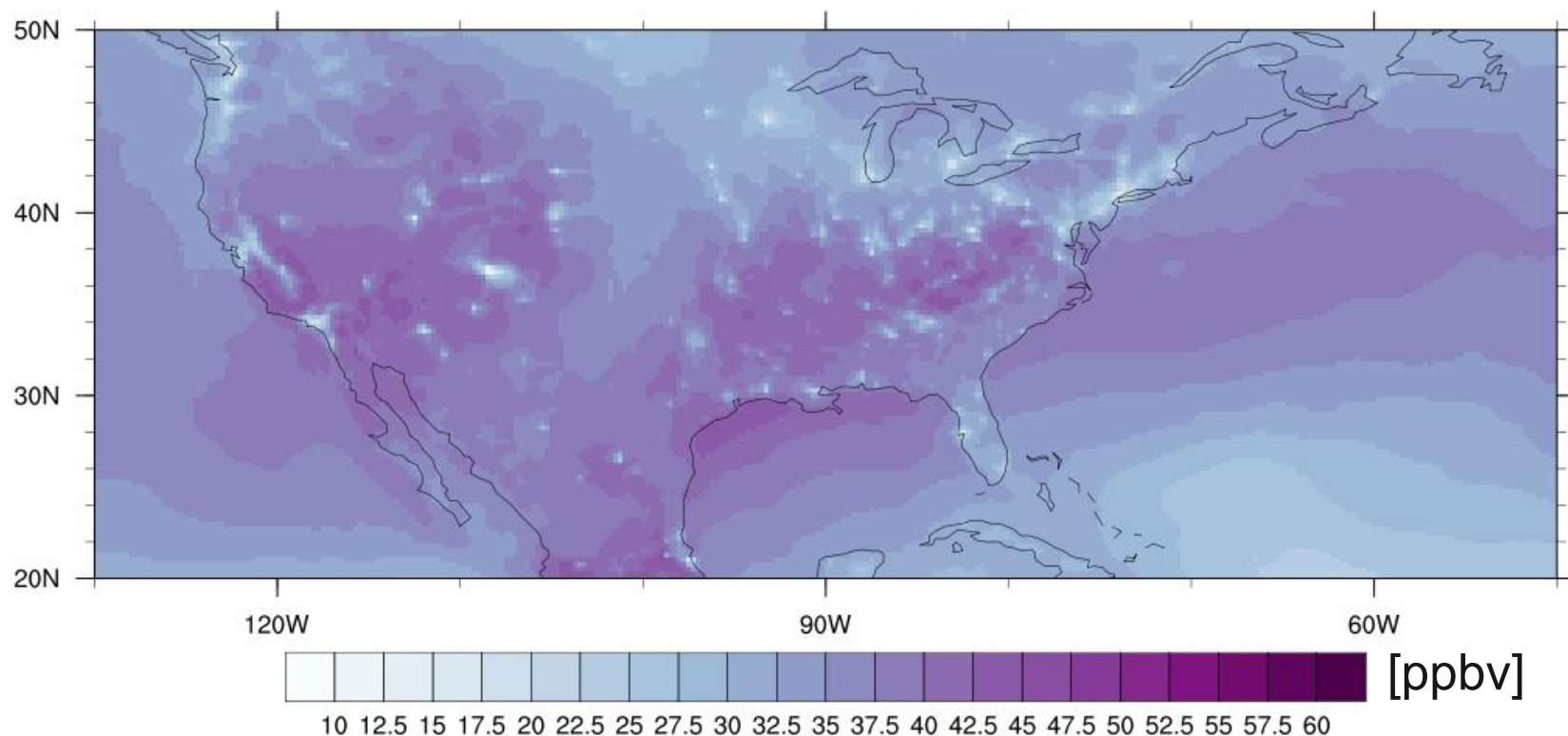
monthly mean  $\text{NO}_2$



- $\text{PM}_{2.5}$  driver of spatial gradients
- $\text{NO}_2$  is Short-lived
- Extreme gradients

# Health Air Quality Index (HAQI or AQHI)

monthly mean  $O_3$

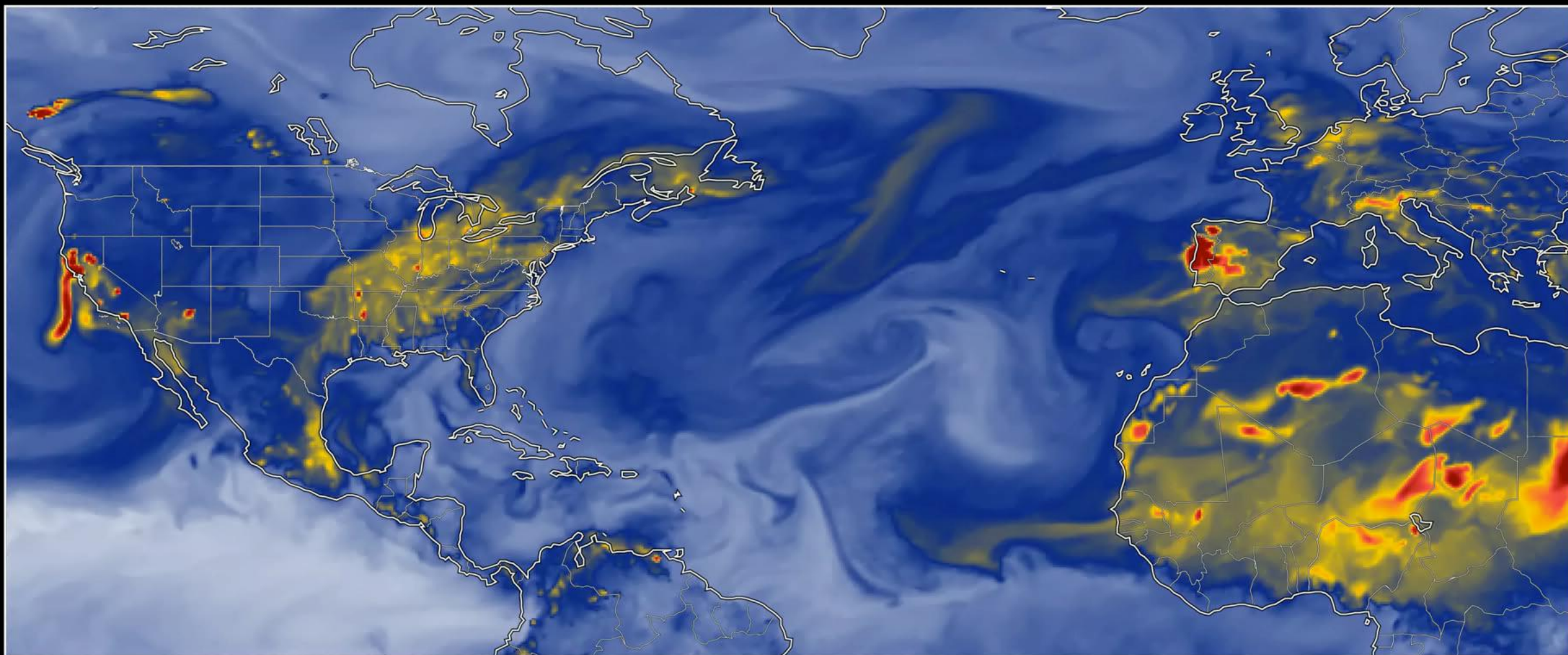


- $PM_{2.5}$  driver of spatial gradients
- $NO_2$  is Short-lived
- Extreme gradients
- $O_3$  influences Background levels



$$\text{HAQI} = f(\text{NO}_2, \text{PM}_{2.5}, \text{O}_3)$$

## Health Air Quality Index



GEOS-5 1/4°

GEOS-Chem v11-02

10 October 2017 11 October 12 October 13 October 14 October 15 October 16 October 17 October 18 October 19 October 20 October 21 October 22 October 23 October



GMAO

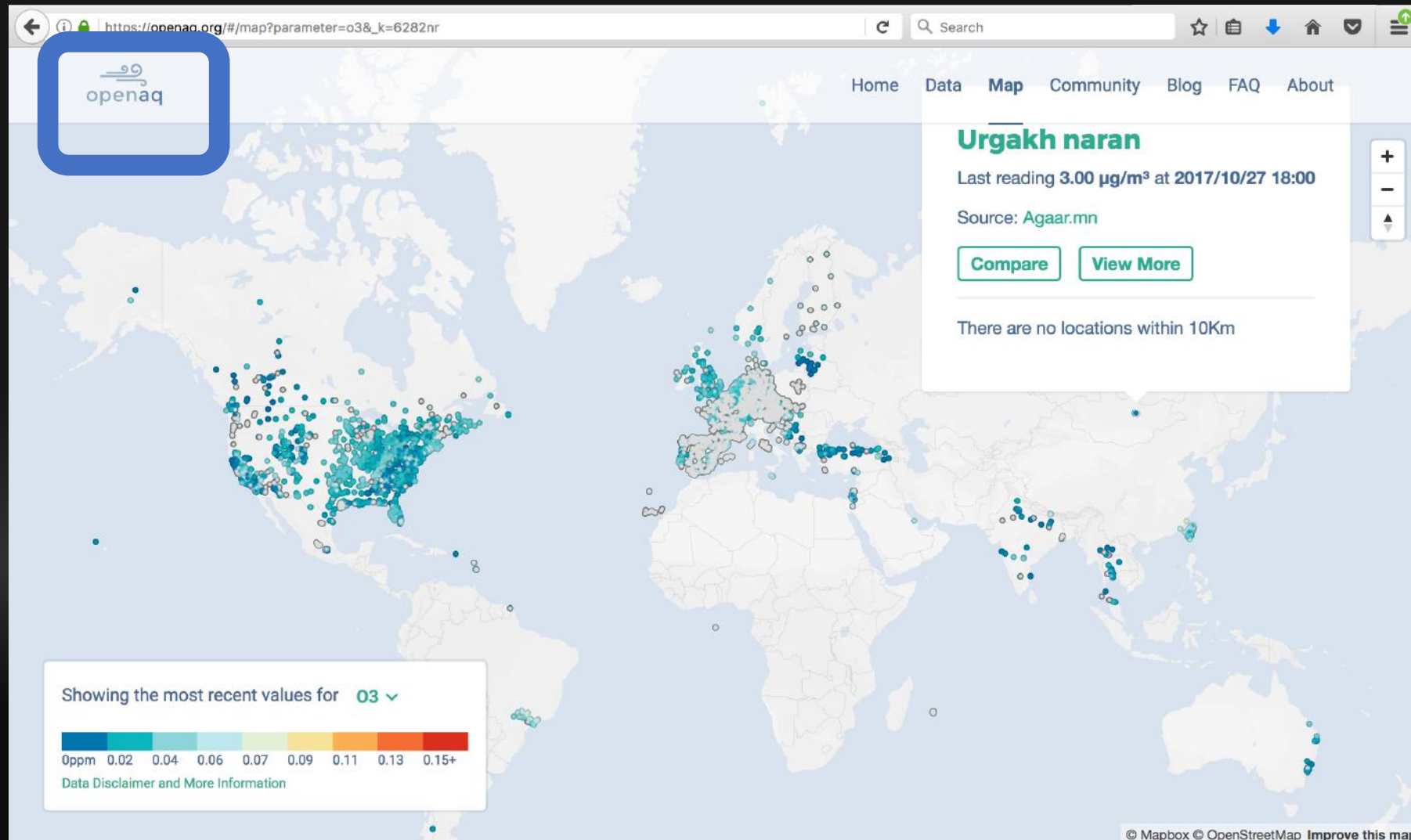
Global Modeling and Assimilation Office  
NASA Goddard Space Flight Center



Atmospheric Chemistry Modeling Group  
Harvard University<sup>2</sup>

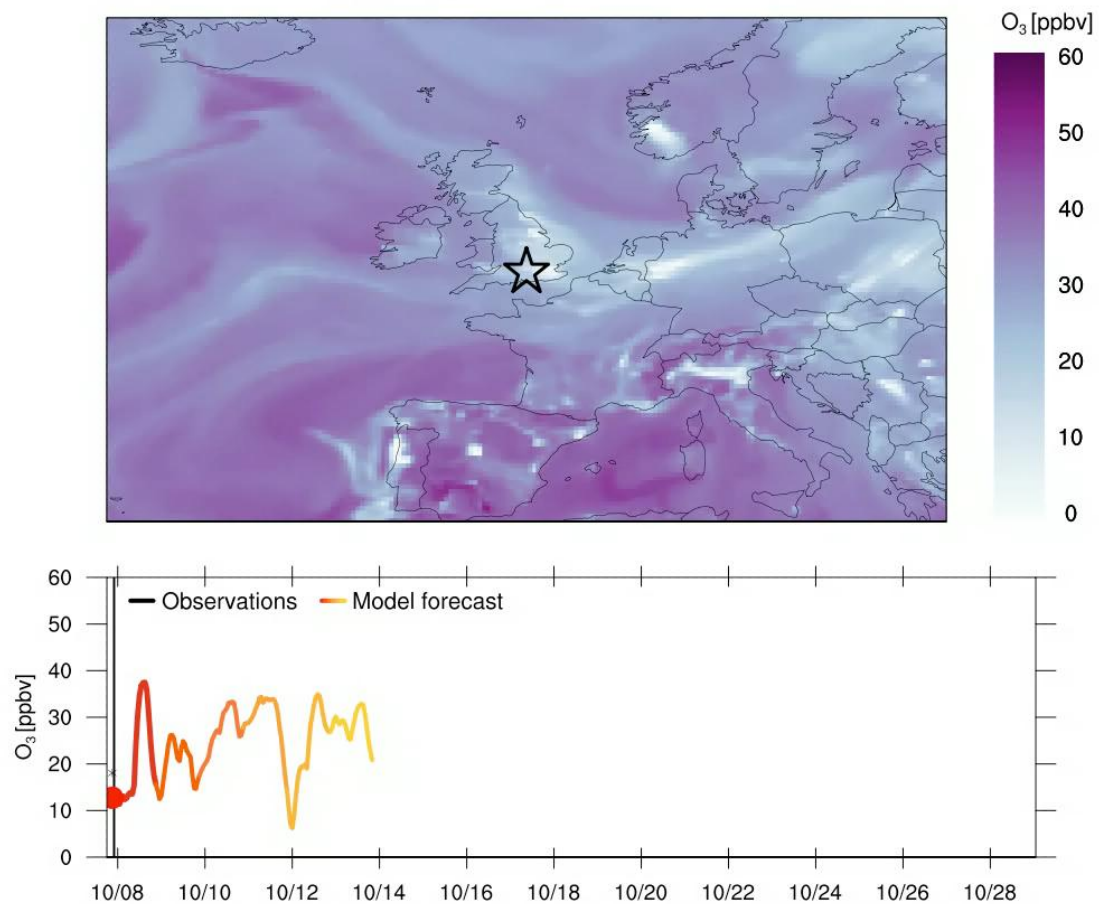


# OpenAQ surface observation data base

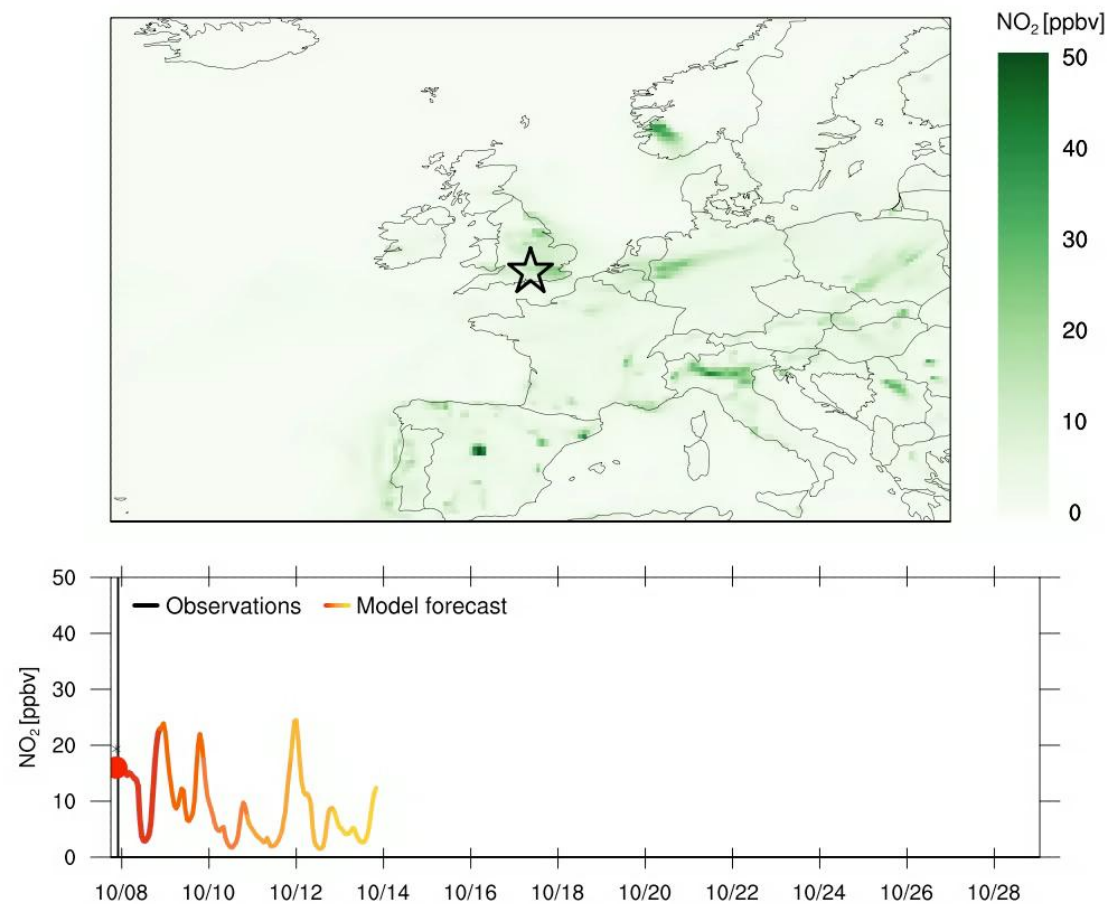


# Observations vs. Model Forecast

Reading, UK, 2017-10-08 00:00 UTC

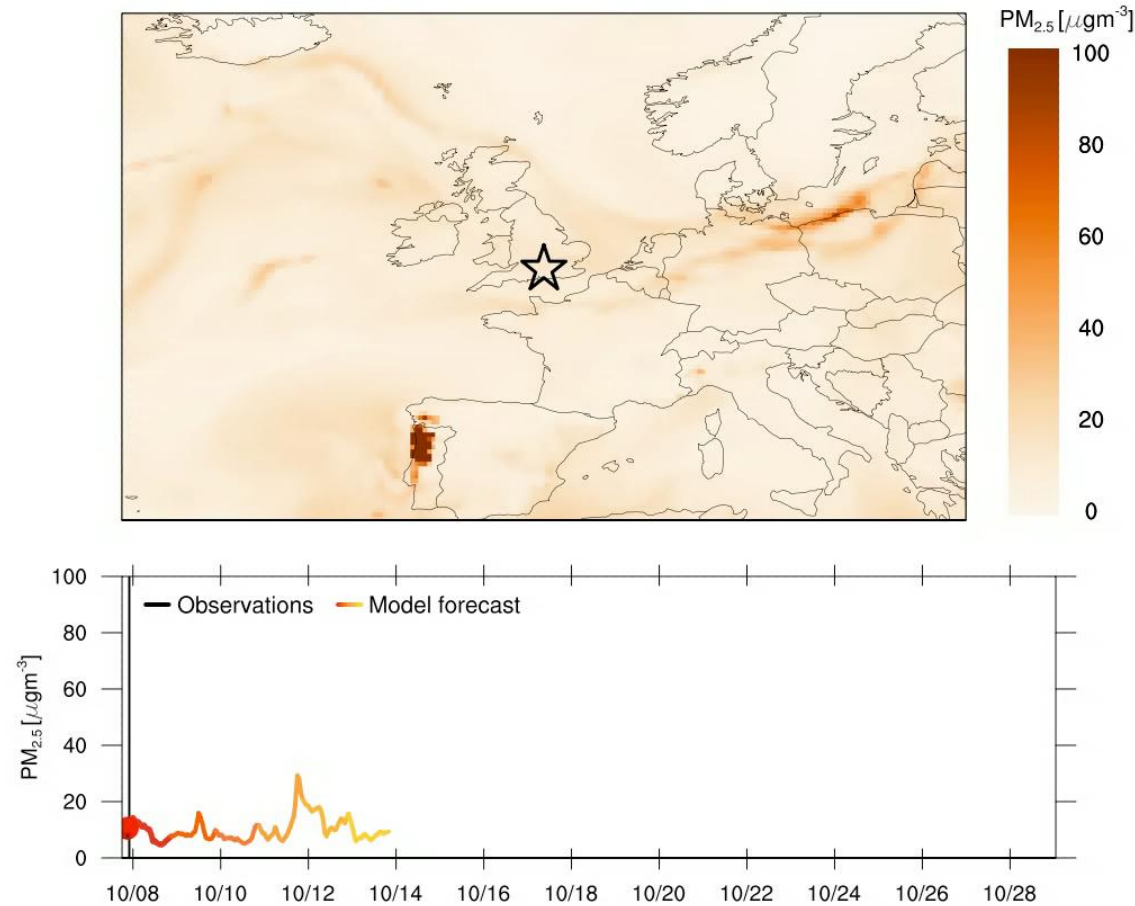


Reading, UK, 2017-10-08 00:00 UTC



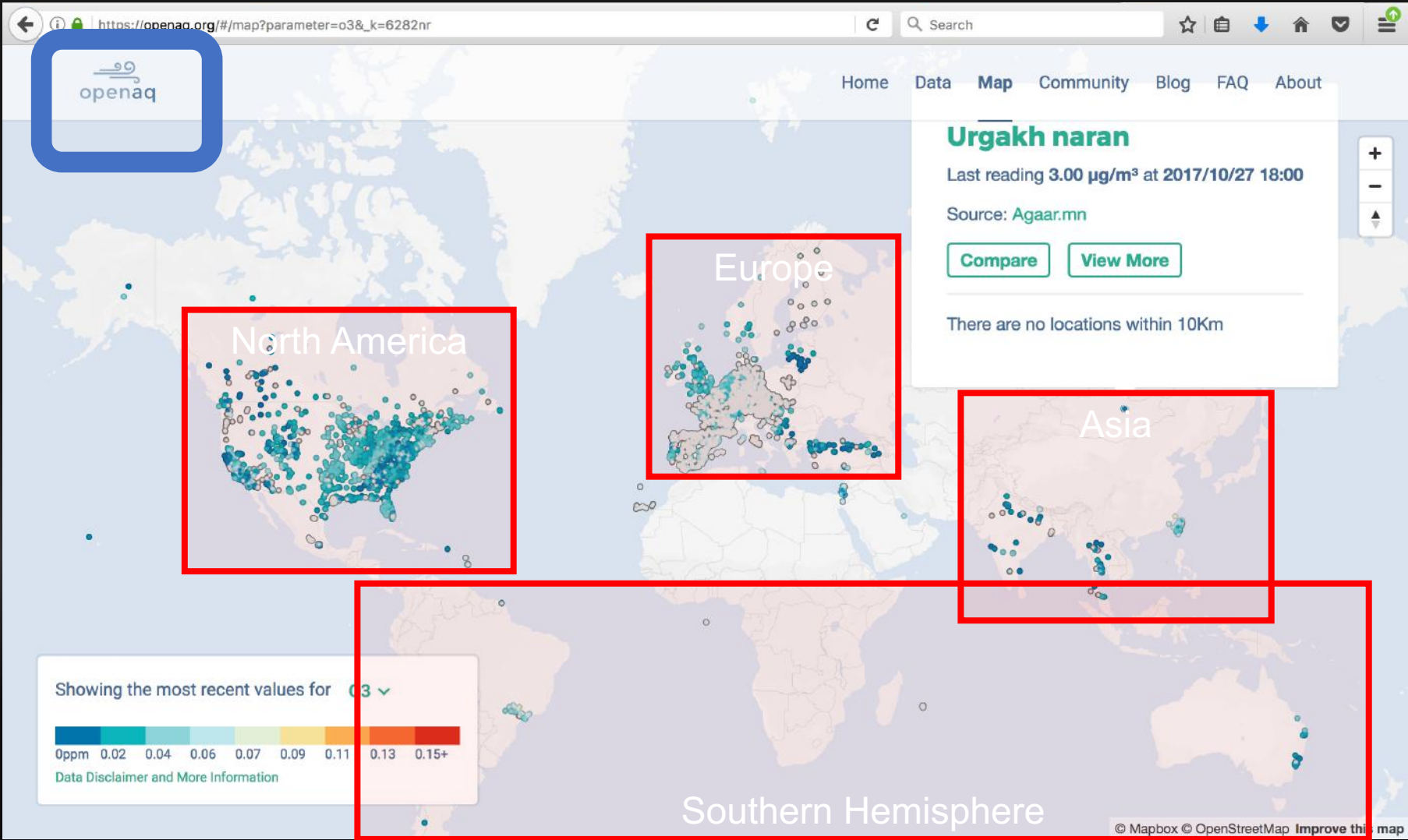
# Observations vs. Model Forecast

Reading, UK, 2017-10-08 00:00 UTC



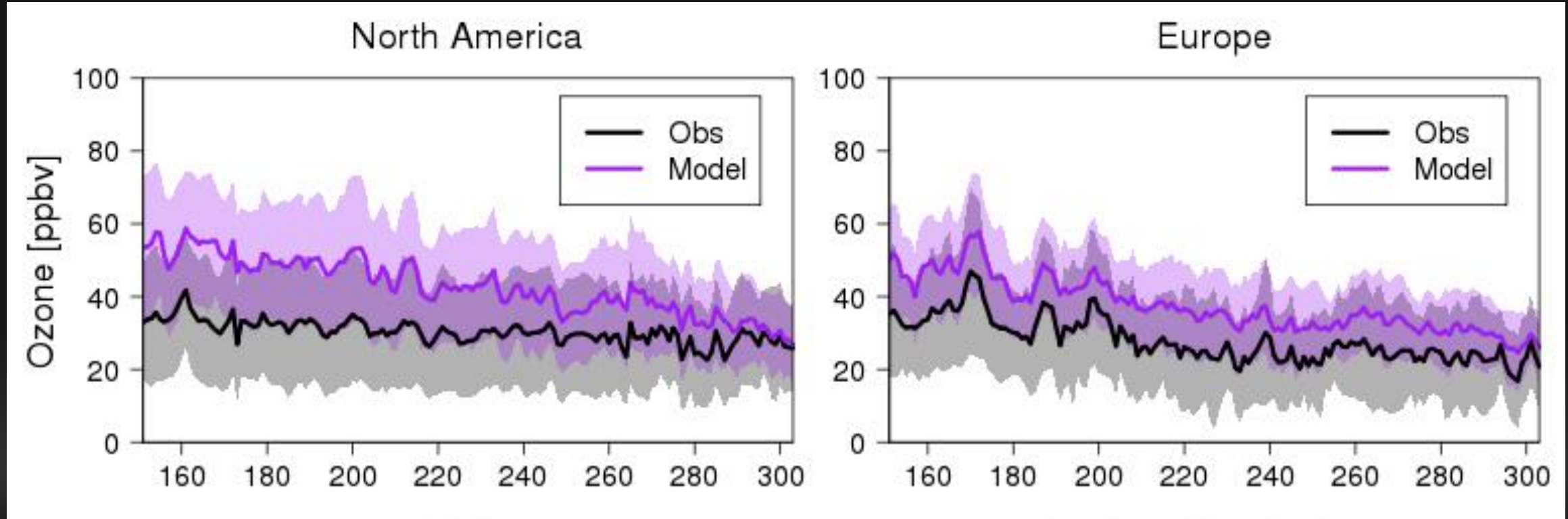


# OpenAQ surface observation data base



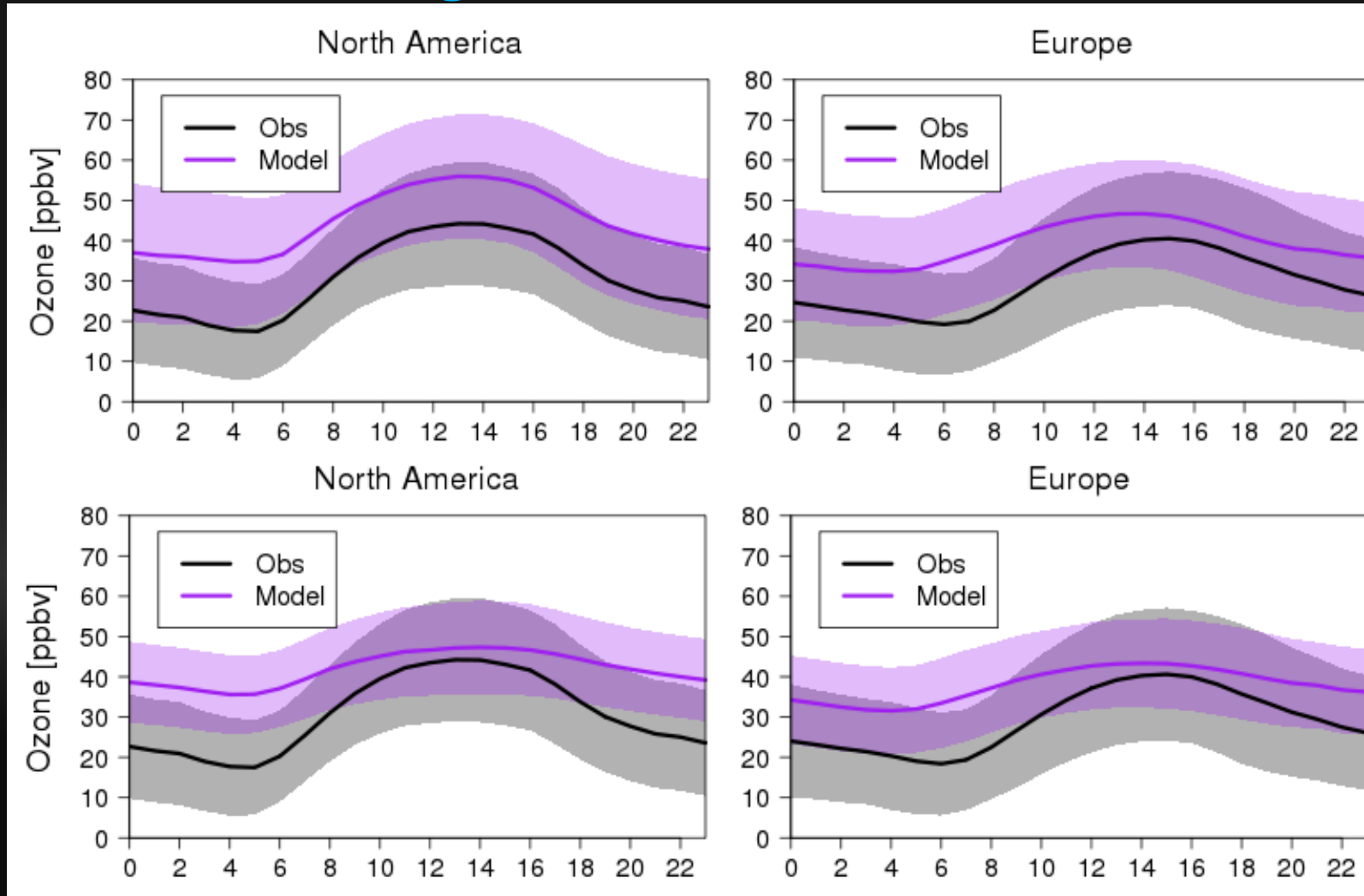


# Surface O<sub>3</sub> observations compared to GEOS CF



# Diurnal cycle of surface $O_3$ is reproduced at the higher resolution

0.25°



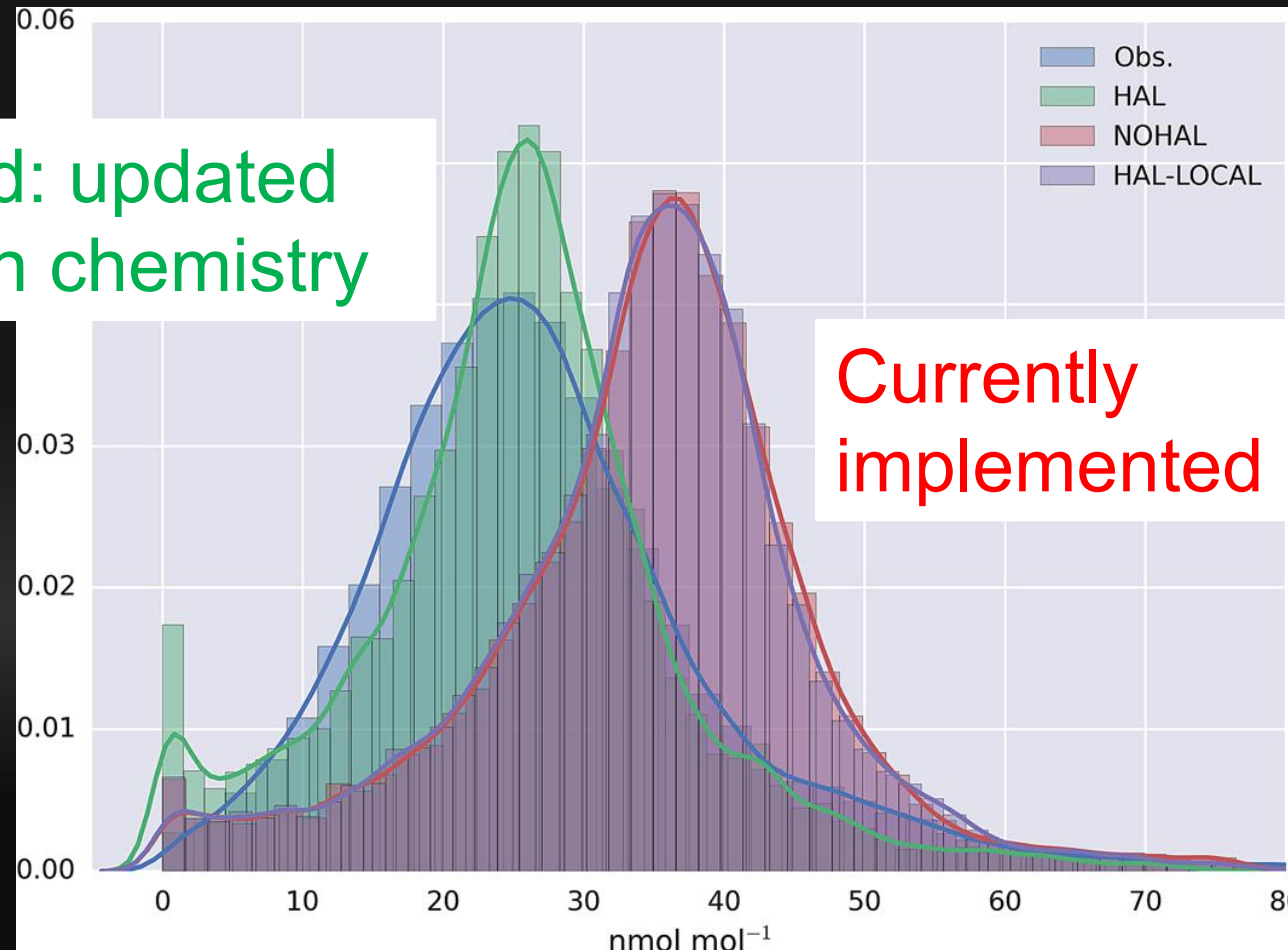
2°

# It is a work in progress....

- Ongoing model evaluation / benchmarking
- Implement GEOS-Chem v11-02d

# Current GEOS-Chem version is known to have high surface $O_3$

v11-02d: updated  
halogen chemistry



Sherwen et al., 2017,  
Faraday Discuss.



## It is a work in progress....

- Ongoing model evaluation / benchmarking
- Implement GEOS-Chem v11-02d
- Share model output in 2018
  - If interested please email one of us  
k.e.knowland@nasa.gov  
christoph.a.keller@nasa.gov